from the 20th to the 26th. In January, 1924, vessels reported that it set in on the 5th and continued until the 9th, during a part of the time rising to the force of a hurricane. In December, 1923, it came as a whole gale (force 10), though not continuously, on four consecutive days. In all these instances strongly developed and persistent high pressure conditions prevailed over the Southern States of the Union. Of all the months included in the 5-year period, January, 1928, was the stormiest, with a known record of 11 days on which winds blew with velocities of from 40 to 75 miles an hour over the Pacific gulf. In the Gulf of Mexico during the same time only one norther was reported by a vessel, and that of force 8 only.

One of the most comprehensive sea reports of norther weather ever received by the Weather Bureau was furnished through the Hydrographic Office by Capt. Arthur Cocks, master of the British steamer *Nictheroy*, San Pedro toward the Panama Canal. While west of the Gulf of Tehuantepec late on the 27th of January, 1928, the wind experienced was light southeasterly and sea oily calm. Quoting from the report:

> At 10:20 p. m. a black cloud shaped as an arch rose from the eastern horizon. At 10:45 p. m. this cloud passed over the ship; by then it had assumed the shape of a perfect curve which extended from the northern to the southern horizon, the width of the cloud being that of a rainbow, the sky otherwise being cloudless, with stars, even those at the lowest altitude, showing brightly. Soon after the cloud passed, it was seen to lose the arch formation and commence to break up into small fleecy clouds, which very quickly disappeared and the sky was again cloudless. About 10 minutes later the wind came from the ESE. at force 3, accompanied by considerable easterly swell.

Abbreviating the report: Early on the 28th the wind backed into east, then northeast by east, and was blowing a fresh gale from that direction by 8 a. m. The sunrise that morning was very red, and the temperature of the air much lower than on the preceding day. At this time a radio report from a steamer 15 miles from shore near the head of the gulf gave the wind as a whole gale from north-northeast, barometer 30.18. At 2 p. m. of the 28th the *Nictheroy* had barometer at its lowest, 30.00 inches. At 4 p. m. the air temperature was 73°, wind northeast by north, force 9, seas very heavy, sky cloudless. Ship hove to. That day "the sun set rosy red in a low haze, the sky from northeast to southwest being purple in color." Conditions were similar at sunrise of the 29th, except that the wind was now northeast in a strong gale, although the sea was decreasing. The vessel was now in the western part of the gulf, while the crest of the causing anticyclone, pressure 30.60 inches, lay over central Texas. At 8 a. m. the temperature had fallen to 68°, and the *Nictheroy* had resumed her course, but it was not until after noon that the wind, then a fresh gale from north-northeast, began rapidly to moderate, and the temperature to rise. The features of the storm which the captain desired to emphasize were (1) the unusual formation of cloud which preceded the wind; (2) the oft-repeated occurrence of three very heavy seas following in succession when the sea was roughest; (3) the moderating of the sea before the decreasing of the wind.

Although the Tehuantepecer is a norther, and probably will always retain that common name, yet it must be recognized that there is a difference between it and the norther of the Plains States and the Gulf of Mexico. The norther to the eastward of the great North American mountain system is a true anticyclonic wind, and may therefore be classified as a gradient norther. The Tehuantepecer, on the contrary, is a wind of the opposite side of the Cordillera, is ordinarily little associated with pressure changes of moment, and is primarily a mere overflow of heaped up air through a mountain pass from the lower part of the basin in which the anticyclone operates. It is, therefore, a derivative or overflow norther, and might be classified as an orographic norther. When the conditions inducing the Tehuantepecer extend sufficiently far to the southward, other overflows of lesser volume appear to occur through the passes of Central America, producing local northeasterly winds on its Pacific coast of a similar character. One of these is found exemplified in the Bay of Papagayo, on the northwest coast of Costa Rica, and is known locally as the Papagayo. The same name seems to be applied to similar winds of neighboring parts of the coast, especially those of Nicaragua and Guatemala.

METEOROLOGICAL PROGRAM OF THE SEVENTH CRUISE OF THE "CARNEGIE," 1928–1931

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551.5

By CHARLES F. BROOKS, Clark University, Worcester, Mass.

The nonmagnetic ship *Carnegie* is known the world over for its magnetic surveys of all the oceans during six cruises from 1909 to 1921. Now the ship, refitted and equipped for special oceanographic and meteorological work as well as for magnetic and atmospheric-electric, is well along on its seventh cruise, one which will carry it 110,000 miles in three years. The *Carnegie* is primarily a sailing vessel of 600 tons, with hemaphrodite brigantine rig. (See fig. 1.) It has also an auxiliary motor capable of 6 knots. The crew is 17 men, and the scientific staff, including Capt. J. P. Ault, numbers 8, 2 of whom, Dr. J. H. Paul and Oscar W. Torreson, have the meteorological observations as part of their duties.

The route covered through March, 1929, and that planned for the remainder of the cruise is shown in Figure 2. The *Carnegie* alternates hemispheres to avoid winter storms. Ports of call are few and far between. Sailing from Washington, May 1, 1928, the *Carnegie* for several days checked its magnetic instruments against indications of land parties, then after a few days at Newport News made a stormy and slow 29-day passage to Plymouth. Easterly and southeasterly winds and gales held up the vessel off the entrance to the English Channel for 10 days. A fortnight each was spent at Plymouth and Hamburg for the completion of the meteorological and oceanographic equipment and for repairs to the ship after the buffeting. Dr. H. U. Sverdrup, of the Geophysical Institute in Bergen, Norway, and research associate of the Carnegie Institution, inspected the vessel and assisted in the scientific installations at Hamburg. Also, many constructive suggestions were made by members of the *Meteor* expedition. The voyage to Reykjavik, July 7 to 20, and thence to Barbados July 27 to September 17, was moderately stormy in the north, but generally quiet in the south except for two gales, one of them in the southern part of the great September hurricane. From Barbados to Panama squalls helped and calms and head-winds delayed progress. At Balboa the ship was again dry-docked and made ready for a long circuit in the South Pacific. After leaving Balboa October 25, two weeks were required to get out of the Gulf of Panama against the constant southwesterly

FIGURE 1.—The yacht *Carnegie* under sail January 14, 1929, in the South Pacific Ocean in latitude 2° S. and longitude 95° W.

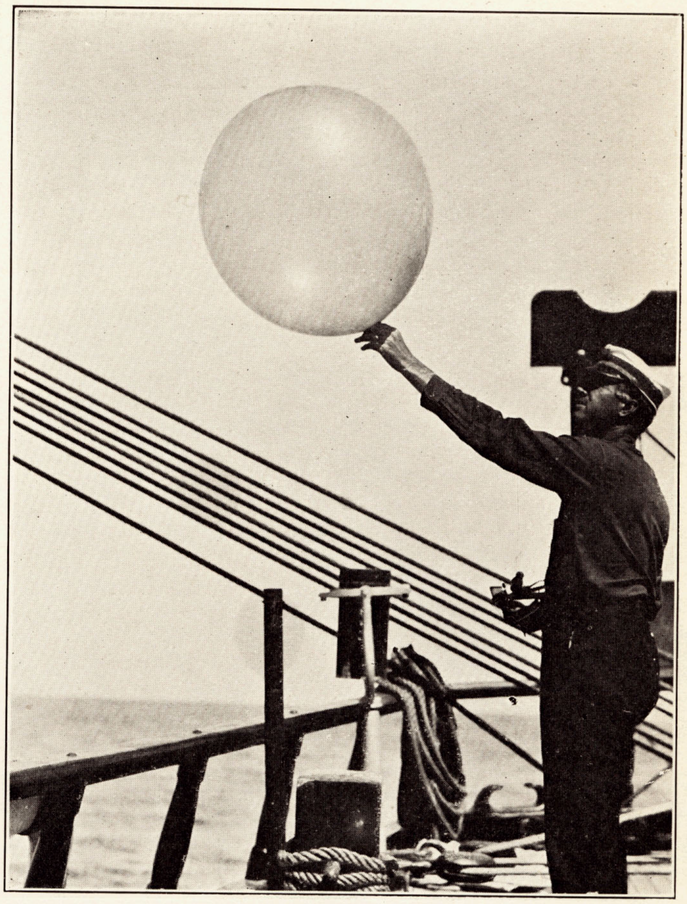

FIGURE 3.—Releasing pilot balloon on board *Carnegie*, South Pacific Ocean. Note the sextant in the observer's hand, and the rain gage on gimbals in the background

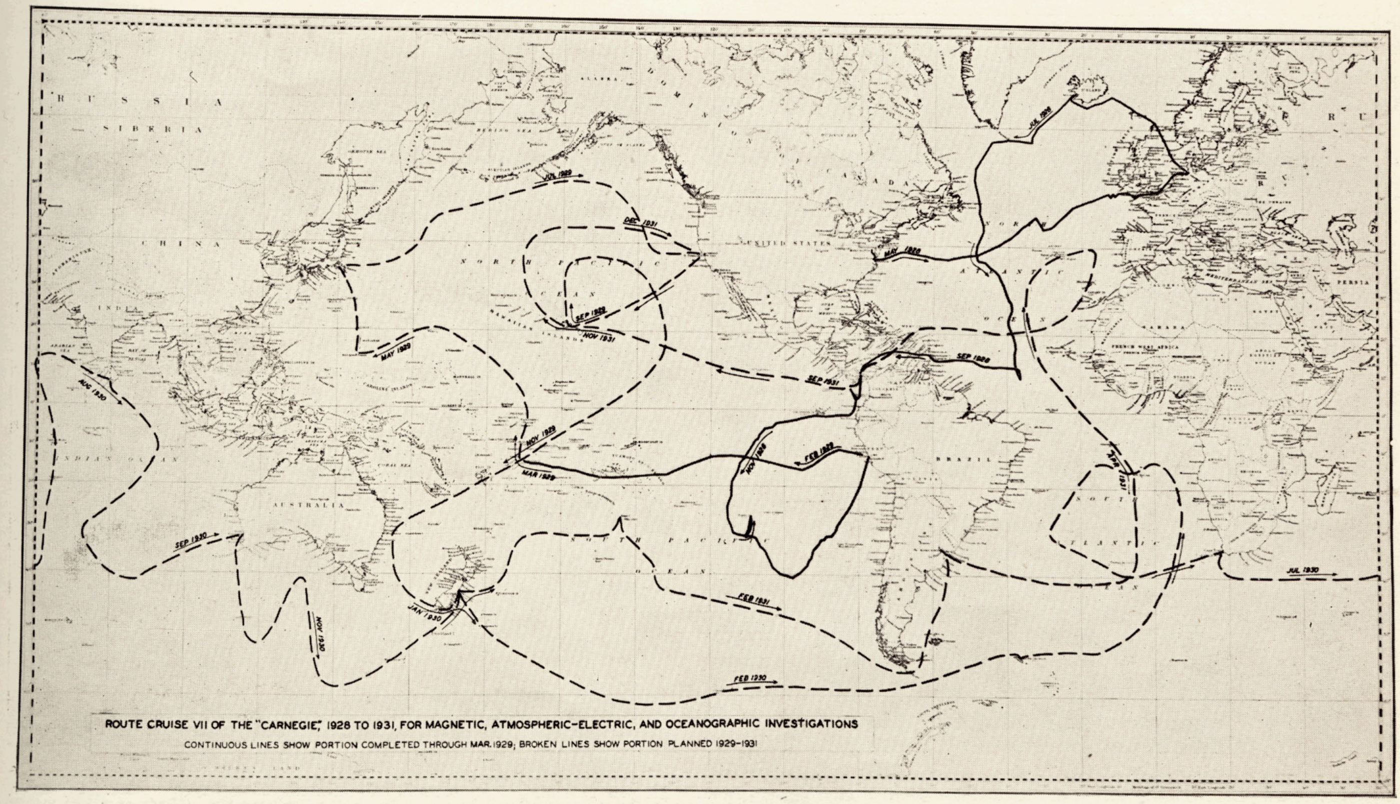

FIGURE 2.—Route of the seventh cruise of the *Carnegie*

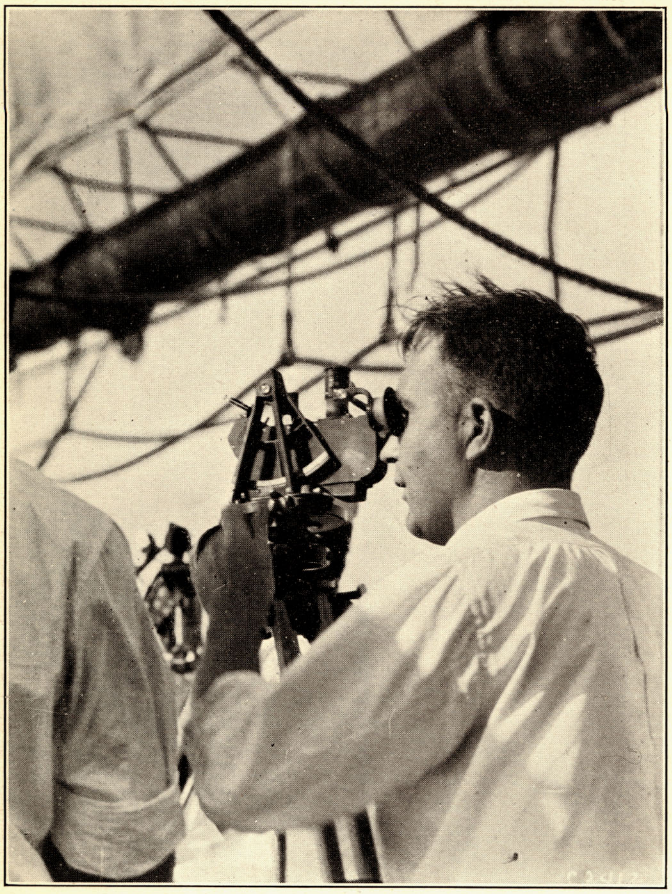

FIGURE 4.—Observing the course of a pilot balloon with the United States Navy theodolite

FIGURE 5.—Observing the course of a pilot balloon with theodolite and sextant. The spring supporting the sextant hangs from a screw eye in the bar over the chair

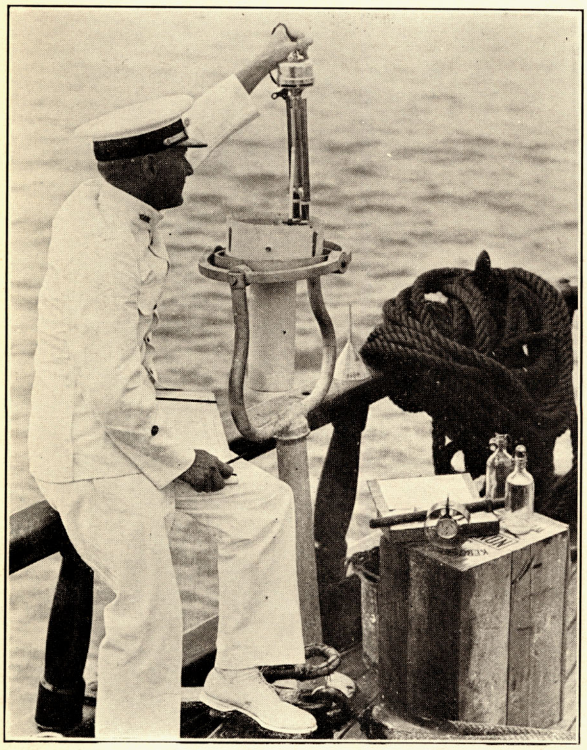

FIGURE 6.—The evaporimeter, Assmann aspiration psychrometer, surface temperature thermometer, and hand anemometer

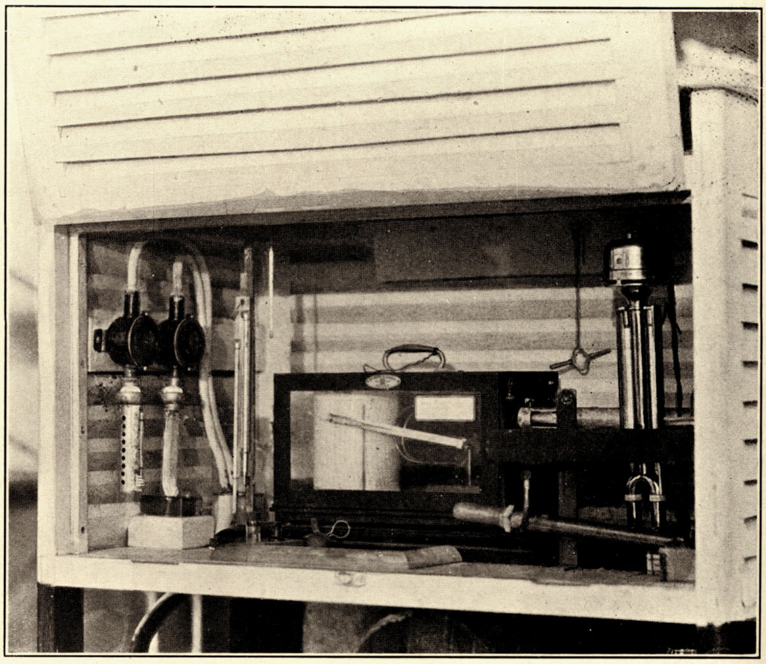

FIGURE 7.—The thermometer shelter, open. On right, wet and dry pair of Hartmann & Braun electrical resistance thermograph, and ordinary sling psychrometer. In center, Negretti & Zambra ventilated wet and dry bulb thermograph. The motor box is just visible at the extreme right, outside the shelter, while the long horizontal bulbs are to be seen at the right in the shelter. The Assmann aspiration psychrometer is at the right

winds, attended by heavy rains and squally weather. But the following two months "were featured by excellent weather, light winds, cool temperature, little rain or fog, and only one gale which continued for six hours." After touching at Easter Island and being driven 300 miles south by head-winds, the *Carnegie* made a good run to Callao, reaching there January 14, 1929.[1] Thence to its May 1 position in the tropical mid north Pacific letters from Samoa and radiograms say favorable weather continued. The expedition will stop in Japan then make San Francisco in August, where the twenty-fifth anniversary of the founding of the Department of Terrestrial Magnetism will be celebrated at that time.

An abbreviation of the magnetic and atmospheric-electric studies of previous cruises has made possible the introduction of a considerable oceanographic and meteorological program in the present cruise.[2] Continuous observations of the weather both by eye and recording instruments are being supplemented by special meteorological work to the extent permitted by the rest of the full program. Preparations commenced more than two years in advance and the experience of the recent *Meteor* expedition [3] have permitted the working out of a highly satisfactory schedule and the installation of the required instruments and apparatus.

Meteorological.—Observations made on previous cruises of the *Carnegie* have been as follows:

1. Continuous record of air temperature by thermograph in shelter on quarter-deck, checked by thermometer reading daily when thermogram was changed.
2. Continuous record of atmospheric pressure by barograph in cabin, checked by aneroid readings daily when barogram was changed, aneroid being checked by mercurial barometer readings once each day at Greenwich mean noon.
3. Greenwich mean noon observations once each day, consisting of readings of mercurial barometer, air temperature, wet and dry bulb readings for relative humidity with sling psychrometer, water temperature, wind direction and velocity (by estimation on Beaufort scale), clouds (form of, direction moving from, and amount), state of weather and of sea, with gale, storm, and for reports.
4. Hourly reports by watch officers of wind direction and velocity, and state of weather and sea.
5. Four-hour reports by watch officers of wet and dry bulb and water temperatures, and aneroid reading, in addition to hourly readings as listed under 4.
6. Special meteorological observations in connection with atmospheric-electric work consisting of hourly observations of mercurial barometer, wet and dry bulb temperatures with sling psychrometer, wind direction and velocity, and state of weather.
7. Observations for atmospheric refraction by dip-of-horizon measurers at 8 a. m., noon, and 4 p. m. Atmospheric refraction was measured also by occasional sextant observations on the sun or Venus when these bodies were near the zenith.
8. Observations were made of the occurrence of thunder and lightning at sea.

Need of further weather observations over the oceans.—Some of the considerations leading to further extended observations over all the oceans on a scientific vessel may be described briefly as the general need for more information about the atmosphere over this relatively unknown two-thirds of the earth's surface, and the particular need for observations of known accuracy and for data from the little traveled ocean expanses that would be crossed by the *Carnegie*. The importance of oceanic centers of atmospheric high and low pressure in the seasonal weather conditions of the continents is becoming appreciated more and more as world weather is investigated. While some areas are well covered with reports, others are very sparsely sprinkled. From some parts of the South Pacific the Weather Bureau a few years ago was receiving but one vessel report per year per 3,000,000 square miles—an area like that of continental United States. And this report was of unknown accuracy, coming from a merchant vessel. Observations by the *Carnegie* on previous cruises and on the present and future ones, in this single area for example, will bulk large in the total scientific knowledge of that part of the earth's surface. Since there is no prospect for fixed observatories over vast stretches of ocean, our knowledge of ocean climatology must be built up by continuing to collect weather data here and there over the oceans wherever and as often as scientific vessels can be sent.

It is perfectly true that observations made with a moving observatory can do no more than note a sample of the climate of each spot passed over. And it is also obvious that unless such samples are recorded now, more next time and more another time, as a vessel passes that way, we shall never have enough of the samples on which to base a general idea of the annual course or ranges of the climatic elements. Each series of samples in intself does not have the value that a corresponding series of depth determinations enjoys, it is true. But that is the nature of what is being observed and does not indicate that this unexcelled opportunity for observing shall not be embraced to the utmost.

Need for ocean-wide observations in greater detail.—Simple observations of air temperature, humidity, pressure, wind, cloudiness, weather, and surface sea temperature, even when indefinitely multiplied by accurate recording apparatus, are very valuable in their way, but fail to show (1) The intensity of solar and sky radiation, (2) the heat budget and storage in the surface layer of the sea, (3) the heat exchange between sea and air, (4) the evaporation from the sea, and (5) winds at various heights.

Comparison of world weather with solar radiation is unsatisfactory without this information, or at least an index to the relative values for different parts of the world at different seasons. The heat exchange of the atmosphere over the oceans—more than two-thirds of the entire surface of the earth—is but little known. Knowledge of evaporation over the oceans can be stated only in the most general terms. We do no know the rate at which the atmosphere is being charged with water vapor vital to the life of the continents. The dynamics of atmospheric circulation over the oceans, and the general circulation of the atmosphere is very imperfectly known, because accurate observations are lacking for such large areas.

The new kinds of observations needed for all the oceans at all seasons are as follows:

(1) Temperatures of the surface layer of the ocean: Surface, 5 meters and 25 meters.

(2) Temperature and humidity lapse rates from sea to masthead.

(3) Wind directions and velocities at different heights, through balloon drifts and cloud motions.

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[1] A running account of the successive trips by Capt. J. P. Ault is being published in Terrestrial Magnetism and Atmospheric Electricity, Washington. The trips from Washington to Callao are described in the September and December numbers, 1928, **33**: 121–128; 192–194, and the March issue, 1929, **34**: 26–31.

[2] Cf. J. P. Ault, The purpose and progress of ocean surveys. *Scientific Monthly*, February, 1928, p. 160–177, 14 ills. Also, in modified form, in *Jour. Washington Acad. of Sciences*, Mar. 4, 1928, 18 : 109–123, map.

[3] See "The steamship *Meteor* survey of the tropical and south Atlantic Ocean," 1 fig. MONTHLY WEATHER REVIEW, February, 1929, 57 : 60–63.

(4) Solar and sky radiation.

(5) Evaporation of sea water. Sea salinities at surface and moderate depths.

(6) Cloud systems, rainfall amounts, dust counts, CO_2 in the air.

All these, happily, could be included in the *Carnegie* program.

The instrumentation includes recorders, so far as practicable. For sea temperatures a bulb-and-capillary type of sea-water thermograph with daily movement has been installed with the thermal element in the keel, about 2 meters below the surface.

Temperature and humidity lapse rates are being continuously recorded with a Hartmann and Braun electric resistance thermograph having three pairs of thermal elements (dry and wet), on the quarter-deck in the shelter, on the crosstrees, and at the top of the mainmast. This apparatus, installed in Hamburg, has given very satisfactory service. The lapse rates recorded are usually normal, while over cold currents the characteristic inversions of temperature occasionally appear. An overheating of the shelter on deck one calm day is recorded as an excessive lapse rate.

For a standard, a bulb and capillary ventilated Negretti & Zambra thermograph is provided in the shelter on the quarter-deck. The difference in the appearance of the mechanically written record of this instrument and of the electrically stamped dot record of the Hartmann & Braun is striking. The constant slight ups and downs of air temperature and the larger variations in wet-bulb temperature, to be noted when a psychrometer is held in the wind on a moving ship, is the cause of some of this broadening of the trace of the Negretti & Zambra instrument. In fact, sometimes for days the wet-bulb temperature will vary a few tenths to 1° C., in the course of 1 to 10 or more minutes while the air temperature remains essentially constant. This instrument is checked daily by an Assmann aspiration psychrometer.

In quiet weather, observations may be made from nearer the water from a small boat, with the Assmann instrument.

Pilot-balloon work was begun when the *Carnegie* left Balboa, thanks to the new theodolite supplied at Balboa by the United States Navy Department. This theodolite, on gimballs, keeps horizon and balloon together and independent of the motion of the instrument as a whole.[4]

"The good weather experienced," writes Capt. Ault,[5] gave splendid opportunity to observe the flights of pilot balloons * * * Practically daily flights were observed; on occasions the balloon could be followed for over one hour before it disappeared, the average being about 20 to 30 minutes. With winds of force 5 Beaufort scale, the balloon would disappear in 13 minutes. Two balloons tied together gave better results. The resulting determinations of the velocities and directions were from sea-level up to a height of from 2 to 6 miles." Six or nine inch red or uncolored balloons have been used, with a computed ascensional rate of 180 or 198 m/min., but, owing to rapid disappearance in brisk winds, red 9-inch balloons inflated to a 250 m/min. ascensional rate will probably be employed hereafter.

The balloons are followed with a sextant as well as with the theodolite. (See figs. 3, 4, and 5.) The sextant has been ingenuously hung on a spring from a bracket over a deck chair, in which the observer reclines at his ease. (Fig. 5.) This has been named the "Joshua chair" after that biblical character who commanded the sun to stand still. Under such favorable conditions the sextant proves to be a good balloon instrument, Captain Ault reports. A total of 44 pilot balloon runs had been made before reaching Callao, while the last radiogram gives 90. These observations constitute a notable addition to knowledge of the winds over the tropical Pacific.

Observations of cloud motions are being made with the balloon theodolite.

For the surface wind direction and velocity, reliance must be placed on estimates, as in the past, except for the indications of a hand anemometer (fig. 6, on box), which is being used particularly in connection with special series of observations of lapse rates and of evaporation.

For solar and sky radiation measurements a Moll solarimeter was supplied. This consists of two horizontally exposed blackened thermocouples, one of which connects with the metal base, covered with a small hemisphere of glass. A microammeter indicates the current generated by the heating effect of the radiation. Dr. Andrew Thomson, director of the Apia Observatory, Samoa, hopes that these observations will show whether a difference exists between stations on land and at sea. The effects of convection even on small islands, such as Samoa, may produce considerable variation in the transmitted radiation from that at sea. Thus far the solarimeter has been little used, chiefly because of the heavy demands of the other work upon the staff.

Evaporimeter and rain gage in turn occupy the same gimbals near the stern. (Figs. 6 and 3.) Continuous sums of evaporation are not being attempted, but observations are being obtained on favorable days. Twelve series were made before reaching Callao. The amount of evaporation is determined by the change in the salinity of the sea water used. The salinity is determined electrically.

Cloud systems are observed regularly at 7 a. m., 2 p. m., and sunset. The heights of cloud bases are being determied from time to time when pilot balloons enter clouds. Dust counts are being made with the Owens dust counter. Of CO_2 observations Prof. B. Helland-Hansen wrote:

> In connection with these ordinary hydrometeorological observations it would be most interesting if a general survey from different oceans can be made with regard to the tension of carbonic acid in the ocean and the atmosphere. As you know, the ocean acts as a buffer with regard to the variations of carbonic acid in the atmosphere, but far too few observations have been made on this point. I suppose the great expedition may furnish us with a classic material in this respect * * *.

Such are the numerous meteorological observations being made on the *Carnegie*. The scientific staff is most industrious, for this meteorological program is but a part of the whole gamut of observations magnetic, atmospheric-electric, biological, and physical oceanographic.

Conclusion.—The meteorological world is to be congratulated on the success already attained and the prospect of a further collection of such careful and comprehensive information from all the oceans; and the Carnegie Institution of Washington, Dr. John C. Merriam, director, and the Department of Terrestrial Magnetism of that institution, Dr. Louis A. Bauer, director, are to be highly commended for making this cruise possible. To J. A. Fleming, assistant director of the department, and to Capt. J. P. Ault, commander of the yacht *Carnegie* belong the chief credit for the program, preparations, and smooth accomplishment.

[4] Cf. F. W. Reichelderfer, Recent types of pilot-balloon theodolites for use aboard ship. Bull. Am. Met'l. Soc., 1928, 9:151-152.

[5] Loc. cit., 1929, p. 28.

[6] Described by L. Gorczynski: Some results obtained by testing solarimeters with pyrheliometric tubes. MONTHLY WEATHER REVIEW, 1927, 55: 488-490, 3 figs.